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Hydro Energy Harvesting by Using Compliant Surfaces. Preliminary Experimental Assessment

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In this work consideration is given for hydro energy harvesting contained in residual water streams. The idea lies in the bifurcation of the stream into two channels separated by a *compliant surface* or membrane which, albeit with equalized static pressure at both sides, nevertheless with a relative velocity. As a result of the differential in the dynamic pressure a steady-state harmonic motion is established which might be transformed into an electrical output. A first experimental assessment of this idea constitute the core of this presentation.

Keywords. *Energy harvesting; Residual waters; Waste waters*

I. INTRODUCTION

Energy harvesting is the process by which residual energy (typically from 1 μ W up to a few mW or thereabouts) can be derived from external sources (e.g., solar power, thermal energy, wind energy, salinity gradients, and kinetic energy), captured, and stored for small, wireless autonomous devices, like those used in wearable electronics and wireless sensor networks [1]. For those readers interested in the research aspects of energy harvesting technologies as well as the current state of knowledge in this field, the book edited by Priya and Inman (2009),[2] is recommended. Despite energy harvesting has been investigated for more than 50 years in several theoretical and practical aspects, there are still a prominent current research growing at rapid pace [3]-[6] not only in specific energy harvesters but also in residual energetic sources. One of this sources is water.

A. Hydro energy harvesting

The object of this work was to investigate a hydrodynamic method by which the kinetic energy contained in those residual waters can be extracted. The idea lies in the bifurcation of a water stream into two channels separated by a *compliant surface* or membrane which, albeit with equalized static pressure at both sides, nevertheless with a definitive relative velocity. As a result, a steady-state harmonic motion is established which could be transformed into an electrical output.

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II. EXPERIMENTAL ARRANGEMENT

A. Set-up

In order to asses the concept, actual experimental investigations were undertaken by using several cavities and configurations until the best design was attained. The experiment was performed in a rectangular narrow cavity 7.5 cm long, 5.5 cm high and 1.3 cm in width, and with two perforations of 0.95 cm in diameter (for the entry and exit of water) and centered in the sides of the cavity at 0.89 cm from the bottom, and the region of the membrane was located at 1.4 cm from the bottom. A stream of fresh water of density $\rho = 1$ g/cm^3 and kinematic viscosity $\nu = 0.01$cm^2/s from a domestic water intake with with a 3.5 bar exit pressure and 290 K of temperature was used for the experiment. The cavity was built with methacrylate for visualization.
The compliant surface was of rubber membrane 6 cm long and 1.2 cm in width and attached to an aluminium frame at the edges in such a way that a gap between the membrane and the wall around 0.05 cm was allowed. This gap has two important contributions, namely: on one hand allows the free transverse motion of the membrane; and on the other hand allows an entry of water from the bottom chamber (the bottom of the membrane region) to the upper chamber (top of the membrane region) and then allowing to equalize the static pressure in both sides of the membrane which is one of the key requirements for the proposed hydro energy harvester. The rubber membrane was with a thickness on 1 mm and with a surface tension around 5.5 N/m for small displacements from its unstressed position. Finally, in order to extract the energy of the vibrating membrane a *linear inductance generator* was chosen which simply consisted of a permanent magnet attached at the surface of the membrane and moving through a coil located vertically. The single coil was a conducting copper wire loop 2 .5 cm long, and with an external diameter 1.0 cm, and internal diameter 2.35 mm, electrical resistance $R = 1000\ \Omega$ and

situated in front of the permanent magnet attached at the membrane and at a distance of 0.4 cm. The coil was fixed at the top of the aluminium frame and aluminium was chosen as non-magnetic material and then avoiding damping effects in the system.On the other hand, the permanent magnet was a strong neodymium magnet of 20 grams in weight, 1.2 cm in diameter and with a magnetic field at its surface of 0.2 T.

The electrical current was produced in the coil as a result of the relative motion of the permanent neodymium magnet attached at the membrane.

The voltage ΔV , resistance R and frequency ω was measured by using a multimeter and oscilloscope and the electrical power W_e by applying the well know formulae:

$$W_e = \frac{\Delta V^2}{R} \tag{1}$$

The water velocity in the cavity U was calculated indirectly by measuring the volumetric flow Q in the water intake by using a simple test-tube and chronometer and then dividing by the cross section of the cavity as $u = \frac{Q}{A_c}$.

III. RESULTS

Form the experimental results, It was found that for a typical residual water with velocity around 1.7 m/s the output power is in the order of 30 mW/ cm ^{2} of area of the membrane and then, by comparison with energy harvesters, it can be rated as a high performance energy harvester.

IV. CONCLUDING REMARKS

A physical hydrodynamic concept has been proposed for the generation of electricity from those waters which although no suitable or with little attractiveness to be turbined because the small drop pressure with the environment, nevertheless still with enough dynamic pressure (velocity).

In summary, the basis of the idea is based in the bifurcation of the residual water into two streams separated by a *compliant surface* (membrane) with equalized static pressure in both sides of the membrane but with relative velocity between both streams. As a result, a steady-state harmonic motion of the compliant surface is promoted which could be potentially harnessed for extracting energy from the system. Theoretical model was developed and analytical expressions derived which agree qualitatively and quantitatively with the experimentation performed.

NOMENCLATURE:

Q = volumetric flow
R = resistance
U = flow velocity
ΔV = voltage
W = power

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